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GEOPHYSICAL RESEARCH WITH THE AID OF ROCKETS AND ARTIFICIAL SATELLITES

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GEOPHYSICAL RESEARCH WITH THE AID OF ROCKETS AND ARTIFICIAL SATELLITES*

By A. A. Blagonravov and M. G. Kroshkin

Rockets and artificial earth satellites have become in recent years an effective means of accomplishing planetary, geophysical and cosmic studies. Their development has gone along two directions. First, there has been wide use of more complicated automatic arrangements for the study of structural parameters of the upper atmosphere, solar and cosmic radiation, magnetic and electrical fields, etc. This direction, being given extensive development in the Soviet Union, has already yielded extremely important results. Their consideration is the basic theme of current articles which represent a survey of informative materials and theses of many Soviet and foreign authors.

The second direction of scientific studies is preparation for the space flight of man. In this field, biological experiments, conducted by the Soviet Union, for the most part on research rockets, have given definite results.

The test of new powerful rockets in January of this year and the major feat in which the Soviet Union on May 15 placed in orbit a gigantic space satellite vehicle, weighing more than four and one-half tons, are important steps in resolving the technical problems present in the accomplishment of space travel by man. The last launching demonstrated that, from a technological point of view, space travel may be already realized. However, for the practical accomplishment of space travel it is necessary to solve many problems connected with guarantee of the safety of a man in flight and his return to the earth.

Man's flight in space is an important link in carrying out research on our planet and especially on other heavenly bodies.

At the same time, observations with the aid of automatically-operated rockets, artificial satellites and automatic interplanetary stations, having become a specific object of geophysical studies in recent years, will be perfected and will play a more important part both in the study of outer space and in the safety of space travel.

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In research with the aid of both rockets and satellites there is a positive and a negative side. With the aid of rockets, for example, a vertical cross section of the atmosphere has been produced, including establishment of a height less than 160 kilometers, below which artifical earth satellites cannot exist. Rockets permit facts to be received at a determined point in space at a determined time. But one cannot recover data by means of rocket soundings over large areas over a prolonged period. Such information may be received with the aid of satellites, but then the possibility of a vertical cross-section of the atmosphere is excluded. In this way, research with the aid of rockets and with the aid of satellites mutually complement each other. A wise combination of these two methods provides reliable information on the structure of the upper atmosphere and its processes and also data on other geophysical and heliophysical aspects of scientific studies.

All investigations realized by means of rockets and artificial satellites, F
by virtue of their leaning toward one or another traditional scientific direction, 5 7
may be conditionally divided into two main divisions: structural thermodynamical and magneto-ionospherical. Helio physical and astrophysical investigations, together with the study of meteors, occupy an independent place. It is necessary to stress the conditional character of such separation; present hypotheses on causes of geophysical processes assume their tight connection.

The research program which the USSR has planned to conduct in the course of the International Geophysical Year (IGY) includes the launching of 125 meteorological and geophysical rockets and several artificial earth satellites with the goal of studying the structural parameters and optical properties of the upper atmosphere and also the physio-chemical processes occuring in it, the investigations of ionospherical phenomona and the earth's magnetic field, cosmic waves, short wave and corpuscular radiation of the sun, micrometeors and meteors.

In connection with this program it was planned to accomplish by various methods the measurement of atmospheric pressure, temperature and density at various altitudes, to determine its composition and obtain data on the variation of these magnitudes in time. This program included the study of ion concentration in an entire thickness of the ionosphere and mainly above the main maximum, the investigation of the periodically short variation of the earth's magnetic field, and also the character of the magnetic fields at great distances from the surface of the earth; investigation of primary cosmic radiation, its intensity and its composition and variations; shortwaves (ultraviolet and Roetgen) which do not penetrate through the earth's atmosphere, and also the corpuscular radiation of the sun, which plays a great part in the formation of the ionosphere. The study of the spectrum of meteors according to masses permits one to evaluate the danger of meteors to satellites and rockets, and from another aspect to give material necessary for proof of those geophysical hypotheses which assumed that various atmospheric processes are caused by the penetration of meteoric matter.

Investigations with the aid of rockets were included in the national programs of the U.S.A., England (held on the Australian testing ground), France and Japan.

Taking into account that the USSR and U.S.A. promised to conduct the rocket investigations in the polar regions as well as in the medial and equatorial latitudes, it may be assumed that rocket investigation of the upper atmosphere was planned to take in the entire world. The launching of artificial satellites, excluding those of the Soviet Union have been included only in the program of the U.S.A.

Successful results of cooperation in investigation of geophysical processes and the necessity of the prolongation of some types of experiments on satellites already launched for example, led to the fact that the International Geophysical Year, at the suggestion of the Soviet delegation at the Fifth Assembly of the Special Committee of IGY meeting in August 1958 in Moscow, was extended into 1959 under the heading of International Geophysical Cooperation (IGC). Investigation was also continued during this additional period with the aid of rockets and artificial earth satellites.

In the course of carrying out the IGY - IGC program, the Soviet Union launched altogether 175 rockets (125 in the period of IGY and 50 during IGC). The launchings took place on Khays Island (Franz-Joseph Land), in the medial latitudes of the regions of the Soviet Union, from the deck of a ship near the south polar observatory Mirny, in equatorial and northern waters of the Pacific Ocean.

The goal of 158 launchings was to investigate the upper atmosphere. In almost all of the meteorological rockets used for this purpose were mounted electro-thermometers for resistance and heated manometers. In some rockets there was an apparatus for optical investigation. By such means much material was collected on stratification of temperature and atmospheric density and their time and latitude variations, on the temperature field in the stratosphere, and on brightness of sky at various altitudes.

Seventeen rocket launchings to altitudes of 100 to 470 km were made in order to carry out the complex research on the structure of the upper atmosphere. The greatest number possible of juxtaposed parameters were obtained. For the first time, spherical self-orientational automatic mechanisms in six of the rockets were used to register the structural parameters of the atmosphere, for optical investigation and recording of physical conditions inside and outside the container. The weight of the spherical container is 367 kilograms.

In seven of these launchings, which were lifted to the altitude of 210 km, the rocket had a detachable fuselage and two capsules, in each in which were installed scientific research apparatus and a hermetically-sealed compartment with research animals. Total weight of the apparatus and animals was 2200 kilograms. Especially constructed parachute systems enhanced hope of recovery of the apparatus and the animals. During the four 1958 rocket launchings rockets, for the first time, a launching was conducted at the altitude of 450 to 470 kilometers which included scientific research apparatus and animals contained in a detachable fuselage. The total weight of the apparatus and animals was 1520 kilograms. The rockets were stabilized in the course of the entire flight, enhancing hope of completing physical measurements with precision. Altogether there were nine launchings of hermetically-sealed capsules with animals and control apparatuses. The table gives data on use of various apparatus for scientific research in the rockets.

While in the process of carrying out experiments on geophysical rockets new data was obtained on pressure, density and temperature of the upper atmosphere, which is necessary for construction of its physical model up to the altitude of 450 km. By means of radio-frequency mass-spectometers the chemical composition of the upper atmosphere was investigated. A determination of the electron concentration in the ionosphere including the region above the main maximum (from 100 to 470 km) was made. It was noted that there were registered not only the number of impacts on the sensitive elements of the micrometers but also their energy. The average frequency of impacts was found to be approximately 1.7×10^{-3} of the impacts per square meter per second, but for the meteor streams one finds a characteristic inhomogeneity and sometimes the quantity of the impacts greatly increased (up to 9 impacts per m^2 per second at altitudes of about 470 km). The registered meteor particles possessed the energy of the order of 10^4 ergs.

New data on the distribution of brightness of day and night sky was obtained. As a result of the investigation of the ultraviolet portion of the solar spectrum, information was obtained on distribution of energy in its separate areas. Experiments from great altitudes were conducted on the photography of the earth's surface and cloud systems. Extensive biological investigations were carried out regarding the influence of specific conditions of rocket travel and physical conditions in the upper atmosphere on living organisms. The safe recovery of the animals and apparatus to the earth was guaranteed.

Apparatus	Number of launchings	Morning	After-Noon	Even-ing	Night
Ultra short wave dispersion Radio interferometer for the measurement of the free electron concentration in the ionosphere.	9	5	2	1	1
Radio frequency mass-spectometer for the determination of ion composition of the ionosphere.	9	5	2	1	1
Apparatus for measurement of positive ion concentration in the ionosphere.	15	6	6	2	1
Apparatus for the measurement of electron temperature.	6	3	2	-	1
Apparatus for the measurement of air pressure.	17	8	6	2	1
Balloons for air intake.	2	2	-	-	-
Apparatus for recording the particle and micro-meteor impact.	15	7	6	1	1
The sun spectograph for recording the ultraviolet spectre region.	6	5	1	-	-
Apparatus for the measurement of the brightness of the sky.	6	1	4	1	-
Apparatus for recording the temperature of the boundary layer of air.	4	-	4	-	-
Apparatus for recording the corpuscular streams.	6	1	4	1	-
Apparatus for the investigation of cosmic rays.	4	3	-	1	-
Apparatus for the measurement of the electrostatic fields in the atmosphere.	1	1	-	-	-
Apparatus for recording the sun's Roentgen radiation.	2	1	-	1	-

The accomplishment of rocket research programs abroad was conducted essentially along the same scientific directions as in the Soviet Union. Their distinguishing pecularity is perhaps the greater subordination of every experiment to some physical problem, whereas at the same time the Soviet Union on one hand conducted an extensive meteorological investigation of the stratosphere and on the other hand complex experiments with the aim of establishing mutual connection between separate physical phemonona and processes. In the last phase the great lifting power of Soviet rockets was used to good advantage.

From the separate physics experiments taking place with the aid of U.S.A. rockets it is possible to note the study of temperature and winds by the use of accoustical methods (with the aid of grenade explosions on various horizons), determination of the density of the atmosphere, investigation of cosmic rays (included in the high geomagnetic latitudes), the investigation of ultraviolet and solar radiation and ultraviolet photography of the sun placing the regions of emission in the Lyman-Alpha line, and also other rocket, astronomical experiments (for example, the recording of ultraviolet radiation from various regions of the sky).

In connection with the IGY program in the Soviet Union we launched three artificial earth satellites. Direct problems which were stated were as follows: determination of the density of the upper atmosphere and its fluctuation, to be carried out by observation of the orbit evolution, as well as by means of direct measurements of the atmospheric pressure: determination of atmospheric composition; investigation of the corpuscular radiation of the sun and the radiation in the shortwave region of the spectrum; recording of the magnetic field at great distances from the earth; ionospherical experiments; study of the composition and variations of cosmic radiations; study of micrometeors; construction of biological experiments under long dynamical non-gravitational conditions. The great power of Soviet rocket carriers permitted launchings of satellites of great weight which in turn has made possible the construction of complex experiments.

On successful completion of all planned investigations, density of the air and ion composition of the atmosphere up to the altitude of 840 km, and electron concentration above the main maximum has been determined by means of observation of the radio-wave distribution, as well as by direct measurements of positive ion concentrations obtained by the use of ion traps. Some characteristics of the magnetic field were discovered: its diminishing with altitude, the character of some anomalies and variations. The piezometer permits one to determine frequency and energy of micrometeor impacts: the average value about 1.7×10^{-3} impacts per m^2 per second (with the brief increase up to 22 impacts per m^2 per second at the altitude of 1700-1800 km.). The energy of the majority of the micrometeor particles is equal to 10^4 ergs and the mass equals 10^{-9} grams. Data was obtained on the intensity and composition of cosmic radiation, its time and latitude variations. Interesting material was obtained while carrying out a biological experiment.

The U.S.A. launched in the (IGY-IGC) period a substantially greater number of satellites than the USSR but as a result of their small size the experiments carried out were characterized by the solution of particular problems mainly related to investigation of cosmic rays and density of the atmosphere. Only the experiment on the satellite Explorer VII (launched on October 13, 1958) had a complex character.

Investigations using satellites became truly international as other countries conducted extensive observations of the motions of Soviet and American earth satellites. Moreover, on the basis of material gathered from these observations, a great many studies on gravitation, astronomy, ionospherical research, etc., were conducted.

The Soviet program of investigations by means of rockets and artificial satellites was completely realized.

On completion of this program, rapid development of rocket technique and equipment made it possible immediately to shift to direct studies of interplanetary space and other astronomic bodies. In this investigation actual physical problems are solved, but they also have a geophysical meaning because they give much data for the evaluation of the mechanisms of geophysical processes, their correlations and stipulations.

Such investigations began with the launching of the first cosmic rocket in the Soviet Union on January 2, 1959, which passed the moon at a distance of 5 to 6,000 km and became the first artificial planet of the solar system. The second cosmic rocket, fired on September 12, 1959, reached the surface of the moon and the third rocket launched the October 4, 1959 went around the moon and, after photographing the far side, it transmitted the photograph back to the earth.

In the course of these launchings investigations of the magnetic field of the earth and the moon were conducted and cosmic radiation, gas components of the interplanetary material, and corpuscular radiation of the sun, and micrometeors were studied. As with the investigations using altitude rockets and artificial satellites, the great lifting power of cosmic rockets made possible the complex nature of the experiments conducted, and the obtaining of juxtaposed physical results. Through the launching of space rockets the following was accomplished: measurement of the intensity of the primary cosmic rays and Roentgen and gamma radiation of interplanetary space, determination of the composition of charged particles, a study of cosmic radiation belts around the earth discovered by the use of satellites, discovery of the systems of outer ionospherical streams at distances of 3 to 9 earth radii from the earth, the measurement of the magnetic fields near the earth, in outer space and near the moon, and evidence that the moon is noticeably lacking in magnetic field.

Only cosmic rays were investigated by the rocket (Pioneer IV), launched by the U.S.A. in March 1959. The second rocket launched by the U.S.A. in March 1960 was a sun probe designed to investigate some characteristics of space near the sun and to prove the possibility of making radio connection over a distance of 10,000,000 km.

Not only countries which launched rockets, but other countries which had the means took an extensive part in the observation of the rockets' orbits. Thus the observation of artificial comets resulting from the launching of Soviet Cosmic rockets and created at determined points in their trajectories was conducted at many astronomical observatories by various countries: by the use of the radio-telescope in Johndrell Bank (England) observations of the motion of the second and third space rockets were conducted.

The use of rocket method for investigation of interplanetary space and other heavenly bodies of the solar system and the need of further international cooperation in this area led, after termination of the IGY-IGC, to the organization of the International Union of Scientific Unions of the Special Committee on Investigation of Cosmic Space, COSPAR (Committee on Space Research). The activity of this committee to a great extent depends on the work of the Special Organization for the Peaceful Use of Outer Space, in the United Nations, and on the solution of several political problems. Also it is hoped that the cooperation of various countries within the framework of this committee will be extremely useful, no less useful than the cooperation which existed during the IGY program.

In the area of rocket technique application, the Soviet Union as in other areas, exemplifies the most sensible use of the accomplishment of science and technology for the good of humanity. All Soviet rockets and satellites were launched for the fulfillment of peaceful scientific programs, whereas at the same time several satellite launchings in the U.S.A. were conducted under a military program. The satellites "Discoverer", "Atlas" and in part "Explorer IV" were designed for the study of the natural radiation belts, as well as for the recording of an artificial belt of charged particles created as the result of high-altitude nuclear explosions (Operation Argus).

These experiments and the use of space and rocket technique for tactless and open espionage, which was made obvious by the launching of an American satellite (Midas), represent a great danger to the fate of international cooperation and provocation from a political viewpoint. Such facts are sharp and unpleasant contradictions to the peaceful investigation in the cosmos conducted by the Soviet Union.

The realization of the geophysical and cosmic investigations program has already led to many major new and unexpected physical conclusions. In short they may be formulated in the following manner.

The earth's atmosphere at great altitudes has greater density and reaches further out than was assumed on the basis of theoretical speculation and indirect observations. The temperature magnitudes at great altitudes also appear to be considerable greater than was previously thought. As an illustration, consider the value of the density and temperature obtained by the third Soviet satellite. At an altitude of 225 km (the perigee orbit of Soviet satellites) the density came out to be 2.12×10^{-3} g/cm^3, while the temperature was 936°K; at the altitude of 300 km correspondingly 3.53×10^{-14} g/cm^3 and 1048°K; at 400 km 6.6×10^{-15} g/cm^3 and 1373°K; and at 500 km 2.21×10^{-15} g/cm^3 and 1953°K. The data relates to the 15th revolution of the trajectory (May 16, 1958).

Strong fluctuations in density of the upper atmosphere and their relation to solar activities were discovered. Observations during IGY were in this sense very favorable because they coincided with the maximum of solar activity when the high point of the five-year, 11-year and centennial cycles took place, possibly with other correlations of solar activity. A tight correlation between the short periodic variation of solar activity and the period of the revolution of the third Soviet satellite became distinctly apparent. The relation between atmospheric density and solar activity is obviously demonstrated by the length of the motion of the third satellite in its orbit, which turned out to be substantially greater than initially computed: with the decrease of solar activity, density of the upper atmosphere and resistance decreased.

The data received concerning the course of yearly temperatures at various altitudes in the stratosphere also determined the character of the temperature variation and the air density in the stratosphere as a function of latitude.

The data concerning magnitudes of the density of the upper atmosphere and its variations together with the direct investigation of the atmospheric streams and other experiments (for example, observation of meteor tracks) indicates the presence of strong air currents and great turbulence in the upper atmosphere.

Mass-spectrometer research led to establishment of the character of ion composition of the upper atmosphere. In part, it demonstrated that above 250 km the atmosphere is mainly atomic in nature with most of the ions being atomic oxygen. Ion concentrations of the second component, i.e., atmospheric nitrogen, constitute from 3 to 9 per cent of the atomic oxygen concentration. Noticeable ion concentration was obtained at altitudes of 1000 km which agrees with the results of the investigation of the atmospheric density.

Ionospheric variations demonstrated that sharply expressed layers of electron concentrations do not exist. There are only local maximums on a monotone curve of increase of electron density up to the maximum layer F_2. Above the main maximum the electron concentration decreases very slowly, becoming at great altitudes an electron concentration of interplanetary matter. (The decrease takes place 5 to 6 times slower than the increase of concentration below the main maximum). By the use of ion traps, concentration of positive ions in the ionosphere was determined. Thus, at the height of 795 km the concentration of positive ions was found to be 1.6×10^5 ions in $1 cm^3$. According to the order of magnitude this corresponds to electron concentration at a given altitude.

The data on ion concentration of interplanetary matter was obtained by means of rockets. The discovered increase of concentration of charged particles near the moon agrees with the results of radio-astronomical observation.

Magnetic measurements, conducted by the third Soviet satellite made it possible to determine the character of decrease of magnetic field with increase in altitude. An analysis of the character of the decrease with at increasing altitudes of East Siberian magnetic anomaly led to a conclusion as to the location of its sources in the earth's core. The discovery of magnetic field variations of short duration at altitudes which correspond to the maximum layer F_2 indicate the presence of current systems in this region of the ionosphere. By means of magneto-meters in rockets, current systems existing at great distances from the earth in the area of radiation belts were discovered.

Data on intensity of corpuscular and ultraviolet solar radiation and also on intensity of cosmic radiation in the upper atmosphere was obtained in the proximate regions of the earth and moon. Again in 1957, use of the second artificial satellite and later the third satellite established a substantial increase in intensity of cosmic radiation with increase of altitude and geographical latitude. With the aid of American research, the belts of cosmic radiation around the earth, and the so-called corona of the earth, composed from particles of great energy held by the earth's magnetic field were discovered. Specific pecularities of Soviet and American satellites greater orbit inclination of the former and greater magnitudes of apogees of the latter led accordingly to the discovery of the inner and outer zones of the earth's corona. Later, by means of cosmic rockets, data was obtained characterizing the overall construction of these high energy particle zones, captured by magnetic field, and the nature of the particles themselves. No increase in the intensity of the cosmic radiation near the moon was discovered, which substantiates its lack of a magnetic field.

The short periodic fluctuation of cosmic radiation intensity at the height of several hundred kilometers was discovered. The isolines of intensity of cosmic radiation turned out not to coincide with the geomagnetic parallels, Not only was recording of the intensity measurement accomplished, but that of heavy nuclei and photons in cosmic radiation as well.

Data was obtained on the density of meteor material in the upper layers of the atmosphere and in interplanetary space, and on the magnitudes and the energy of micro-meteor particles.

The character of the relief of the hidden side of the moon was established as a result of its being photographed. A mountain chain called "Sovietskim" was discovered and two seas and some craters were also named.

The medico-biological experiments demonstrated the ability of a living organism to endure the overload during rocket take-off and a prolonged condition of weightlessness.

The results obtained by various methods substantiate each other. Likewise, the results of Soviet and foreign research concur thoroughly.

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Study of structural parameters of the atmosphere and ionosphere, of the magnetic field, and of radiational characteristics which has been conducted up to the present time gives a sufficient concept of the general conformity of their distribution to basic law. It was established also that these magnitudes are not all static, but subject to considerable change. From the physicist's view of the atmosphere, the most important problem of research by rockets and artificial satellites is the study of the nature of these changes - systematic as well as sporadic.

It is difficult, nay, even impossible to make any assumption about the sequence of future geophysical experiments with the aid of rockets and artificial satellites. Thus it is seen that every new stage of investigation to a considerable extent is determined by the results obtained while carrying out the preceding stages. Naturally, therefore, in speaking of future rocket investigations, it is necessary to keep foremost in mind the most imminent problems now considered most interesting.

Without touching upon such general, independent, physical problems as the testing of the theory of relativity, the study of the nature of gravitation, or independent astrophysical and exobiological problems, we shall briefly investigate some general problems which have immediate practical bearing on the study of geophysical correlation on which it is to our advantage to concentrate first of all.

It is necessary to study in greater detail the air streams at various altitudes, the degree of their turbulence, the pressure and density of the atmosphere above the entire surface of the earth, the clarification of the character of changes of all these parameters with geophysical latitude, their seasonal and daily variations, and also local and temporary anomalies. The determining of these variables should give a clear picture of the kinematic scheme of the general circulation of the atmosphere, of the reciprocal influence of its separate elements and partly of its dynamic fields. The solution of this problem offers the very greatest difficulties of an economic and a methodical character. It is evident that in order to obtain these facts from the entire thickness of the atmosphere, a much greater number of rocket launchings in a great number of places and over a sufficiently prolonged period is necessary. The determination of the minimum number of places and the maximum admissable intervals of time requires at least an approximate knowledge of the scales of probable dynamic inhomogeneities and the minimum time of their sporadic variation. The use of artificial earth satellites for this goal does not thus far appear to be possible, with one exception - when the motion of air masses, which are characterized by optical properties different from that of the neighboring medium, may be observed (for example, the observation of the motion of cloud systems).

Not only the changes of the structural and thermodynamic parameters may be used in studying dynamics of the upper atmosphere, but also the changes of the electron and micrometeor concentration to the extent that they indicate hydrodynamic processes; also to be taken into account is the role of the electromagnetic, dynamic effects in the change of the condition of the upper atmosphere.

Thermodynamical characteristics of the atmosphere are of extreme interest. This division of investigation consists of a detailed study of the temperature system in the entire thickness of the atmosphere over all of the climatic zones and also of the variations within this system. It is necessary at the same time to know the radiational order and composition of the atmosphere, including water vapors and non-gaseous particles which may bear on thermodynamical balance: the possibility of change in the radiational balance, thermic influences at the cost of aggregate transition and the stimulation of this transition by dust particles (the latter refers principally to the lower atmosphere). This problem is closely connected with the preceding one and to a considerable extent is similar. It differs in that it is more possible to use artificial satellites, for example, to determine the components of the radiational balance and the concentration of matter in a layer.

With the help of satellites, the temperatures of a stratum of atmosphere may be determined according to the heat radiation which characterizes these layers of a particular matter. The infra-red spectrum of the atmosphere has a sharp selectivity; as a consequence, heat radiation depends strongly on wave length. In the areas of intense absorption only the radiation of the outer part of a layer will reach the satellite. One may determine the temperature of a layer by means of recording the radiation. Ozone, carbonic acid, and water (thinly concentrated in the upper atmosphere) also belong to the number of strongly radiating components of the atmosphere. The use and development of this method of determining temperature can substantially aid the study of the thermodynamic system of the atmosphere.

Concerning the study of the thermal condition of the upper atmosphere (and perhaps not only there), the problem of the sources of its heat is extremely important. This heat was detected during research by rockets and artificial satellites. With the aim of determining the possible sources of this heat and explaining its function, several factors were evaluated. An ultraviolet study of the sun and the influence of meteorite particles turned out to be insufficient to explain it.

F 57 According to Chapman's hypothesis, which explains the heat in the upper atmosphere by means of thermic influence by particles in the solar corona, the earth is located in the outer part of an highly heated corona of the sun. The temperature of the sun's corona near its surface is accepted as equal to 10^6 °K and at a distance, equal to the average distance of Mercury from the sun, about 2.9×10^5 °K and at a distance, equal to the average distance of the earth from the sun, about 2.2×10^5 °K. The shortcoming of this hypothesis is the static of the sun's corona and the arbitrary character of the coefficients of thermal conductivity which are accepted in the computation of M. Nikola. Other hypotheses likewise do not now satisfactorily explain the heat in the upper atmosphere. Isotropy in particular does not permit an explanation of the time variations of temperature in the upper strata of atmosphere. It is essential to conduct a special study of all the possible agents of heat, which, of course, can be done only be means of rockets and artificial satellites, to find a solution to this problem. First of all this concerns a detailed study of the corpuscular emanation of the sun, which is one of the most probable sources of the heat of the upper atmosphere, and it also concerns a study of the sun's radiation in the shortwave section of the spectrum, of interplanetary gas, of the earth's crust and of the current system in the upper atmosphere.

Another unsolved problem is the formation of large-scale structural heterogeneities of the ionosphere and the formation of layer F_2. Concepts of structure of the ionosphere and concentration of electrons in separate strata, which were pooled to work out the results of ground radio-probing of the ionosphere, were not corroborated by the first ionospheric investigations using rockets and satellites.

The hypotheses which were then presented to explain the separate layers do not give a complete explanation of all the properties and texture of the atomsphere and therefore can not be considered proven. Particularly difficult is the explanation of the simultaneous existence of the local maximum F_1 and F_2.

In general the mechanism which forms layer F_2 is more complex than the mechanism forming the other layers. On the basis of the computations regarding the theory of the "simple layer" which was formed by radiation with some coefficients of absorption, it should be located lower than it is in reality. There are typical anomalies for layer F_2 in a period of maximum electron concentration, for example the displacement of the maximum in a 24-hour period into the evening hours, the anomaly of the seasonal course of noon values of electron concentration, the latitude course of maximum concentration, etc. It is impossible to explain by the decrease of atmospheric density with an increase of altitude the decrease of the electron concentration, because at the level of the peak of electron concentration only a small proportion of oxygen is ionized (approximately 1/10,000).

The most plausible explanation of the formation of the peak F_2 is considered to be the result of electron diffusion through neutral air which is caused by the force of gravity, while uninterrupted decreases of concentration of electrons and the formation of new electrons caused by radiation is taking place. In that case, the concentration will decrease exponentially upward in accordance with the scale of altitudes. The computations resulting from that presupposition show a sufficient concurrence with natural measurements. Naturally, such a statistical presentation of layer F_2 just as with all the ionosphere is insufficient.

The movement of electrons depends strongly on the general movement of the molecules in the atmosphere and electrical fields. With higher densities of air the electrons shift more easily under the effect of atmospheric movements than do the electrical fields, while with lower densities it is the reverse. In region E atmospheric flows can transport electrons, which lead to currents, which stipulate the changes of the magnetic field and the redistribution of the spatial electrical charge which causes electron movement in level F_2. A detailed explanation of the above is lacking, owing to the difficulty of presenting and explaining the anomalies which take place in layer F_2.

In order to solve the problems of layer F_2, to explain the ionospheric heterogeneities as well as to solve in detail other ionospheric problems, it is now necessary to have such initial data as the density of ionospheric gas, the general density of the atmosphere which determines the character of diffusion, the density of molecules which determines the rate of decrease in the concentration of electrons and the magnitude of the electron velocities which are stipulated by the action of electric fields and also the variations of all these magnitudes. Naturally, these problems can be solved only by means of direct experiments with rockets and satellites. The solution of these problems is pertinent not only in a strictly inospheric sense but also for the solution of various problems connected with the hydrothermodynamics of the upper atmosphere.

Detailed study of the radiational balance of the earth presents a complicated problem. The earth's climate and weather is determined in the final account by the radiation of the sun. It follows that integral energy radiation from the sun changes little with time, many investigations propose that solar activity does not show an immediate influence on the meteorological processes which develop solely under the influence of internal dynamic factors in the system of the atmosphere in its upper layers.

At the present time the albedo of the earth can be only approximated by complicated indirect methods.

Another point of view is based on the statement that processes taking place on the sun and in the atmosphere of the earth have a close physical connection. The statistical tie between the sun's activity and various meteorological, hydrological and even biological phenomona is the basis for such statements. Thus, for example, a connection is observed between the eleven-year cycle of solar activity and the intensity of meridinal shift in the atmosphere, also between the level of bounded reservoirs and the flow of rivers, the growth of wood over a year and the composition of human blood. A precise presentation of the mechanism of all these variables does not exist, but up to the present time they have been attributed to the influence of the unstable portion of the sun's radiation spectrum-ultraviolet and Roentgen rays. In this connection, as the criteria of solar activity, the "Wolf" number (for sunspots) was taken.

Currently, in explaining geophysical connections, a greater value is being given to the sun's corpuscular radiation which, together with specific peculiarities in the physics of the sun, led to the search of new crit eria which might better correlate solar activity with geophysical phenomona than the Wolf number. The proponents of helio-stipulation of meteorological phenomona proceed from the assumption that the atmospheric processes are unstable, or have very small reserve of stability and, therefore, require comparatively small energy of reaction in order to change their course. Thus it is considered that the reaction carries a relay character.

Independent of the controversy over which point of view is true, it is clear that the investigation of the time and latitude pattern of the sun's radiation and the reflection the sun's radiation by the earth is necessary, and while the study of integral radiation characteristics is not sufficient, the "scanning of the spectrum" is necessary.

The investigation of the earth's magnetic field is of the same importance. Up to now, no exact understanding of the causes which stipulate the presence of the earth's magnetic field exists. Data on variation of intensity of the magnetic field at great distances from the earth, obtained by the help of magneto-metric measurements in cosmic rockets, does not coincide with the data which was theoretically calculated under the assumption that the magnetic field is caused by a system of electric currents in the fluid nucleus of the earth.

There is a basis on which one may assume that the magnetic field and its variable component played a great role in the atmospheric and meteorological processes. Detailed knowledge of the earth's magnetic field and its variations will help to clarify the mechanism of this assumed influence.

The study of the open corona of the earth by artificial satellites is as important for the general study of the physics of the space surrounding the earth and its connection with the interplanetary medium and solar activity, as it is for the solution of the geophysical problems, and of related phenomona, which the corona may directly or indirectly influence. Evidently the most important question now is the question of the origin of the earth's corona, and of the sources of the charged high-energy particles which have fallen into the magnetic trap of the earth.

Presently, not only have the geometric forms of the corona belts and their location relative to the earth been established, but also the character of the particle motions along the force lines. Corona variations in time and their dependence on solar activity is established. The most mystifying element in the structure of the corona is the presence of the gap between its inner and outer zones. There is no basis to assume that this is brought about by the structure of the earth's magnetic field. Evidently, this situation is explained by the nature of the particles comprising the belt and their energy spectrum. The belts in turn may depend on the sources of the formation of these particles. The existing hypotheses concerning the origin of the solar outer belt and the origin of the earth's inner belt at the present time have not yet been experimentally proven.

Further study of the earth's corona by rockets and artificial satellites together with the investigations of corpuscular radiation of the sun and the primary cosmic radiation may give an answer to these unsolved questions.

It is important to know the natural evolution of our planet in order to solve some geophysical and climatological problems.

The data contained in geological information is insufficient. We may hope that the investigation of other heavenly bodies which have a common origin with the earth, but which have been developing physical conditions different from those of the earth will contribute greatly to the understanding of general laws of evolution of the solar system and also that of the earth.

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Some unsolved problems are connected with the study of micro-meteoric matter of interplanetary space and its penetration into the atmosphere of the earth. There are hypotheses in connection with which the micrometeors may cause ionization of the upper atmosphere. The hypothesis of Bowen assumes a greater role of micro-meteors and cosmic dust in the precipation, i.e., the particles of solid matter are the nuclei of condensation and crystalization and may in this manner stimulate the formation of clouds and precipitation. Whether these hypotheses will be proven or not is a question of time. The investigation of interplanetary substance may give some data for their proof.

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In relation to this, the realization of human flight to other heavenly bodies will produce information which will be of particular value. The advantage of having a human in a cosmic laboratory as compared to research through automatic equipment will be, first of all, that a human being may change the program of the experiment depending on already obtained results and direct the investigation in a more favorable and effective channel. In particular this is important for geological and biophysical investigations.

The launching of a space ship into orbit around the earth, a new successful flight of a one-stage ballistic rocket with research animals, and the launching of a multi-stage ballistic rocket on July 5 and 7 compels one to assume that the realization of human space travel and the investigation of other planets ceases to be a fantasy.

The accomplishments achieved so far in carrying out planetary, geophysical and cosmic investigations, in spite of their grandeur, are only the beginning. The future of peaceful use of rockets and satellites promises still more brilliant accomplishments which will bring to man additional knowledge of the secrets of nature and enable him to further subordinate the elemental forces.

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